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THE CONDITION FOR FOEHN FORMATION OVER THE NORTH CAUCASUS,(U)
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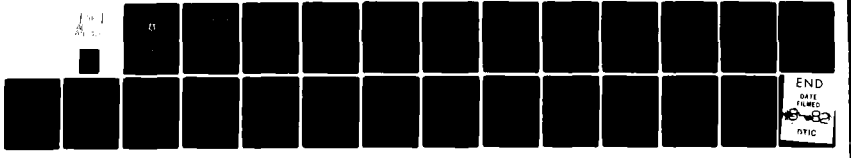

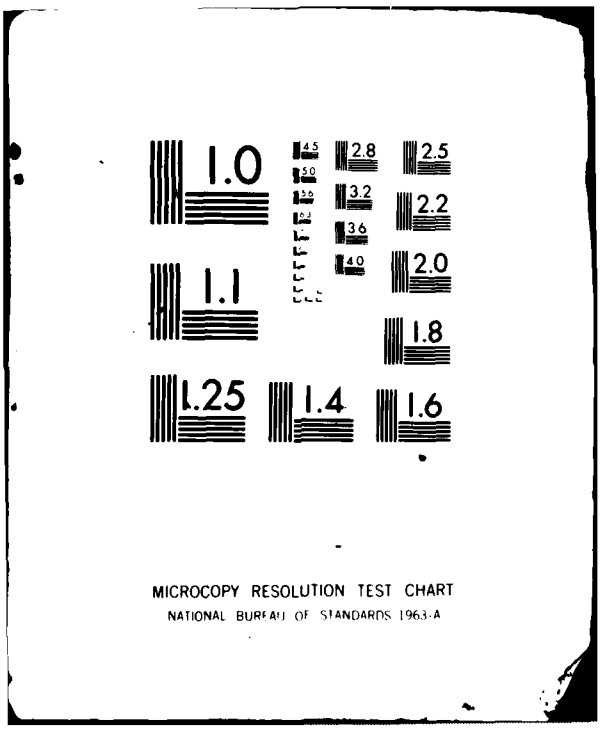
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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963-A

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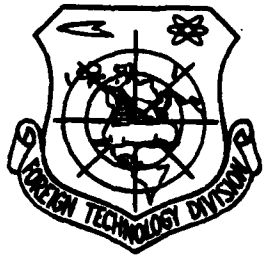
FOREIGN TECHNOLOGY DIVISION

THE CONDITION FOR FOEHN FORMATION OVER THE NORTH CAUCASUS

by

T. Taylakov



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Block	Italic	Transliteration	Block	Italic	Transliteration
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Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
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М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yë or ë.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	sinh^{-1}
cos	cos	ch	cosh	arc ch	cosh^{-1}
tg	tan	th	tanh	arc th	tanh^{-1}
ctg	cot	cth	coth	arc cth	coth^{-1}
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

THE CONDITION FOR FOEHN FORMATION OVER THE NORTH CAUCASUS.

T. Taylakov.

Are examined some characteristics of foehns aloft.

In North Caucasus region were up to now investigated mainly the foehns, which become apparent on the earth's surface. Data sequence about such foehns is in works [3, 4]. Meanwhile aerological observations show that the phenic flow omitted from the summits relatively rarely reaches the surface of the Earth. Usually its lower boundary lies/rests on the height of several hundred meters. For synoptics have great practical value and the foehns, which do not reach the surface of the Earth, since phenic air at the heights, retaining high temperature and low humidity, can be transferred by air currents to the large distances from the mountains and have a noticeable effect on the evolution of the fronts not only near the mountains, but also far from them.

On maps of baric topography for the years 1962-1965 were selected the cases when above the Caucasian ridge/spine were observed the winds of southern rhumbs/bearings. For explaining the presence in these cases of the foehn effect were plotted a curve stratifications of temperature and humidity according to the data of radiosounding stations Mineral'nyye Vody and Makhachkala[1].

FOOTNOTE [1]. Data of Makhachkala for the years 1963-1965. ENDFOOTNOTE.

In the descending foehn air the lapse rate is close to the dry adiabatic and the deficiency of the dew point is increased downward. As an example Figs. 1a and b gives two cases, temperatures characterizing usual vertical distribution and humidities with the foehn.

The analysis of aerological data showed that the existence above Caucasus of the winds of southern rhumbs/bearings yet is not sufficient condition for the necessary emergence of the clearly expressed foehn on the lee side of mountains. Thus, fairly often in Mineral'nyye Vody and Makhachkala are noted southern upper winds, but is not observed the usual foehn distribution of temperature and humidity on the height.

Within the 4-year period indicated above were discovered 78

cases in which the presence of foehn did not cause doubts. In work [4] it is indicated, that in summer in the North Caucasus the foehns on the surface of the Earth do not become apparent. The analysis carried out by us showed that at this time of year it is not possible to reveal/detect foehns also aloft. Beyond upper boundary of foehn was accepted the level, beginning from which with the lapse rate, close to the dry adiabatic, the deficiency of the dew point downward sharply was increased.

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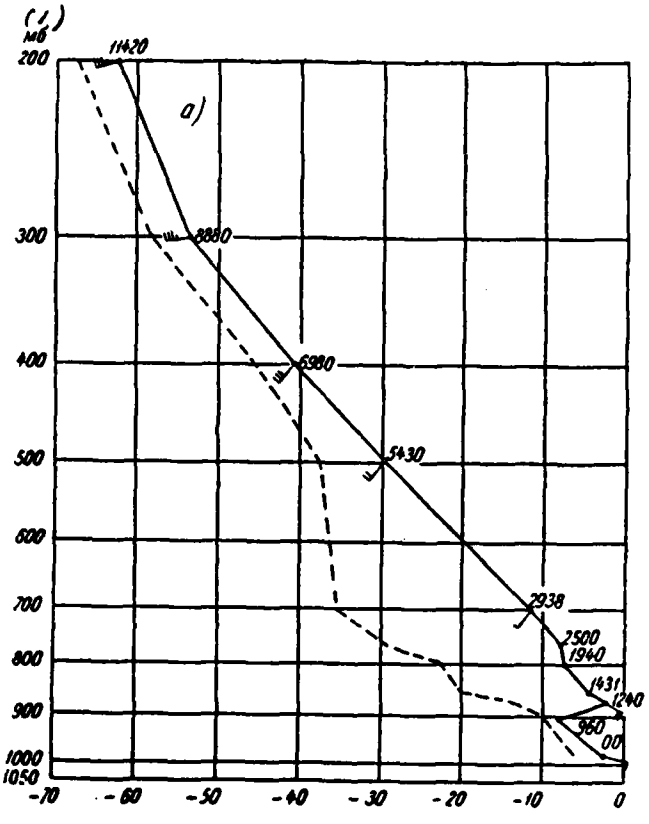

Fig 1.

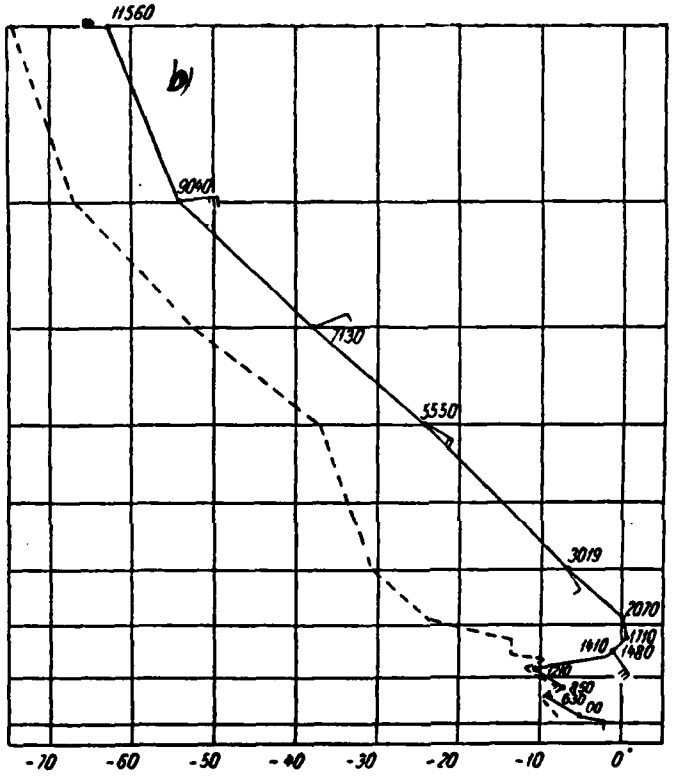

Fig. 1. Vertical distribution of temperature and air humidity with foehn in region of cyclone (a) and anticyclone (b).

Key: (1). mb.

Lower boundary of foehn in cases when it reached the surface of the Earth, was considered upper boundary of foehn inversion. This inversion, as is known, is characterized by a strong decrease downward of the deficiency of the dew point. On the height of lower boundary of foehn strong effect can exert diurnal temperature change. In spring and autumn daytime heating of air on the surface of the Earth frequently destroys foehn inversion. However, in these cases lower boundary of the foehn usually can be detected from the sharp decrease in the lower layer of lapse rate.

The height of upper boundary of the foehn at Mineral'nyye Vody and Makhachkala most frequently lies/rests at the height close to 5 km. Sometimes it drops to 3 km. In many instances the lapse rate, close to the dry adiabatic, and large deficiency the dew point are observed to heights, considerably exceeding 5 km, and they stretch to the tropopause. Here, obviously, is reflected the influence of the orographic waves, indicated by A. A. Dorodnitsyn [2]. The height, with which is outlined the depression of the air above leeward slope of mountains, depends on the character of pressure field. In the upper-level anticyclones with the intense regulated descending motions in upper half of the troposphere the depression of air can begin from the tropopause. In the cyclones the depression of air caused by mountains can begin also from the high altitudes, the considerably exceeding height mountains, but upper boundary of the

descending motions here never reaches the heights, which are observed in the upper-level anticyclones.

Attention is drawn to the fact that the increase downward the deficiency of the dew point at the level, close to 5 km, is observed not only in cases when the depression of air begins at this height, but even when it occurs also in upper half of the troposphere. Thus, the height of 5 km is the basic upper boundary with which begins the foehn flow above the North Caucasus.

In Mineral'nyye Vody lower boundary of foehn most frequently is located at the height close to 1 km while in Makhachkala - at the height of approximately 0.7 km. Sometimes foehn reaches the height only of 1.5 km.

For determining the values of a change in the temperature, point of dew and relative air humidity, caused by the mountains descending motions on the lee side, for Mineral'nyye Vody and Makhachkala were calculated the differences between the actual and advective values of these elements/cells for the 12-hour time interval (within the initial period air particle was located on the lee side of mountains). It was considered that these differences reflect foehn effect, i.e., it was assumed that in the absence of mountains the temperature and humidity in Mineral'nyye Vody and Makhachkala would

be equal to advective. In cold half of year diurnal temperature change at the heights, as is known, is small. Changes found thus in the temperature, point of dew and relative humidity are illustrated by Table 1, in which are cited the data for 15 arbitrarily selected cases.

The average values of a change in temperature, dew point and relative humidity in 12 hours for all 78 cases examined are given in Table 2. From this table it is evident that with an increase in altitude the effect of foehn becomes apparent to a lesser degree, moreover a change in the nodule of dew foehn influences more strongly than to a change in the dew point foehn influences more strongly than a change in the temperature. This is explained by the fact that on the average of the troposphere the difference between the dry adiabatic and actual lapse rates is less than the lapse the dew point.

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When $\gamma<\gamma_a$ ascending air motion are hindered/hampered and the latter, meeting on its way the mountain range, attempts to flow it from the sides. Therefore the cases when to the lee side of mountains comes the air, which rose first on the windward ones to their slopes, must be rare. Especially this relates to the large mountain masses.

It is more probable, that along the lee side of mountains more frequently is lowered the air, which was moving on the windward side of higher than the summits, i.e., for Caucasus the air, which was being moved at the level is is 700 mb. and higher. This assumption confirms the fact that with the foehn precipitation on the windward side of mountains is relatively rare. Of 30 cases of foehn examined on the lee side of the mountains precipitation on their windward side fell only 9 times.

For those cases when precipitation on the windward side of mountains did not fall, were determined the approximate values of descending air motion with the foehn. In the absence of precipitation as an indicator of vertical motions can serve the dew point. The latter virtually is unchanged from the descending vertical motions at the heights where no longer is manifested the effect of the underlying surface. Its small changes, caused by a change in the pressure, easily can be taken into consideration.

The values of the descending motions were determined as follows. In the days with the foehn appeared themselves the initial points of the 12-hour particle trajectories of the air, which moved to this (final) period to the lee side of mountains (in Mineral'nyye Vody or Makhachkala). Trajectories were constructed for surfaces of 700, 500 and 400 mb. The trajectories of the surface of 850 mb. were replaced

by trajectories at the level 700 mb.

Table 1. Semidiurnal changes in temperature (Δt), dew point (Δt_d) and relative humidity (Δr), caused by foehn.

(1) Случай	850 мб (2)			700 мб (2)			500 мб (2)			400 мб (2)		
	Δt	Δt_d	Δr	Δt	Δt_d	Δr	Δt	Δt_d	Δr	Δt	Δt_d	Δr
(3) Минеральные Воды												
1	5	−9	−55	4	−5	−45	2	−2	−10	0	−1	−13
2	5	−8	−38	3	−5	−35	0	−3	−26	2	0	−17
3	3	−9	−37	3	−13	−60	2	−2	−9	—	—	—
4	3	−12	−45	4	−12	−61	0	−5	−23	—	—	—
5	4	−11	−50	4	−12	−69	2	−6	−16	—	—	—
6	5	−4	−48	6	−3	−54	3	0	−9	—	—	—
7	4	−14	−76	4	−6	−34	—	—	—	—	—	—
8	3	−4	−28	2	−9	−38	0	−7	−40	1	−5	−29
9	5	−9	−50	4	−15	−60	0	−14	−55	0	−6	−43
(4) Махачкала												
10	4	−8	−30	1	−5	−20	2	−5	−10	—	—	—
11	7	−11	−54	4	−10	−25	2	−7	−18	2	−6	−18
12	7	−6	−36	1	−9	−30	2	−4	−23	2	0	−18
13	5	−7	−35	6	−1	−23	0	−1	−15	1	0	−20
14	8	−9	−43	4	−13	−45	3	−12	−40	2	−5	−33
15	3	−3	−37	3	−11	−36	2	−16	−11	0	−13	−21

Key: (1). Case. (2). mb. (3). Mineral'nyye Vody. (4). Makhachkala.

Table 2. The average values of semidiurnal changes in the temperature, dew point and relative air humidity with the foehn (1962-1965).

(1) Поверхность (мб)	Δt	Δt_d	Δr
850	5,0	—8,0	—48
700	3,0	—7,5	—44
500	1,8	—5,0	—22
400	1,5	—4,0	—23

Key: (1). Surface (mb.).

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At initial point in the trajectory for the initial period of observations were plotted a curve stratifications of temperature and humidity. On the curve of humidity were located the levels, at which (taking into account correction for changes in the pressure) the values of the dew point were equal to its values on surfaces of 850, 700, 500 and 400 mb. in Mineral'nyye Vody (or Makhachkala) within the final period of observations. The difference in the values of pressure between the obtained levels and the pressure on the appropriate isobaric surfaces indicated directly the value of descending air motion. For example, if at Mineral'nyye Vody within the final period of observations the dew point to $AT_{...}$ was equal - 11°, on $AT_{...}$ - 17°, on $AT_{...}$ - 30° and on $AT_{...}$ - 40°, and at

initial point in the trajectory corresponding of the value of the dew point (after the introduction of correction for changes in the pressure) were observed at the levels with pressures by 670, 580, 430 and 370 mb., then hence it followed that the values of descending motions were respectively equal to 180, 120, 70 and 30 mb. The cases were selected so that initial points in the trajectory on all three surfaces would be located near Sukhumi or Tbilisi - aerological points, nearest to the southern slopes of large Caucasian ridge/spine. The obtained values of descending motions for the examined 20 cases are given in Table 3. Data of this table confirm the fact that to the lee side of mountains is omitted the air, which was being located earlier higher than the summits. With the height the intensity of foehn flow weakens.

Table 3. Values of descending air motion on the northern slope of Caucasus.

(1) Нисходящие движения (*мб*/12 час) на поверхности (*мб*)				(2) Направление и скорость ветра (*м, сек*) на поверхности (*мб*)	
850	700	500	400	850	700
		(3) Минеральные Воды			
180	70	—20	00	ЮЗ—3	ЮЗ—2
200	160	60	00	ЮЗ—2	ЮЗ—7
260	150	100	60	ЮЗ—3	ЗЮЗ—8
180	80	90	60	ЮЗ—2	ЗЮЗ—2
140	180	00	—10	ЮЮВ—10	ЮЗ—5
—[1]	130	70	50	ЮЮВ—15	ЮВ—7
140	00	—50	20	ЮЮВ—5	ЮЮВ—10
150	00	00	30	СЗ—2	ЮЗ—10
160	70	20	30	СЗ—2	З—3
—[1]	120	100	20	ЮВ—7	ВЮВ—7
170	160	130	60	ЮВ—8	ЮВ—3
160	110	80	—20	ЮВ—13	ЮЗ—5
150	150	70	00	ЮЮВ—7	ЮЗ—7
		(4) Махачкала			
180	200	100	40	ЮЗ—7	ЮЗ—5
180	160	30	00	З—3	Ю—5
140	70	60	00	—[2]	ЮЗ—5
140	80	120	60	З—5	ЮЗ—5
—[1]	140	50	30	ЮЮВ—10	З—5
150	30	—50	20	ЮЗ—5	З—3
160	50	—50	—40	ЮЮЗ—5	ЗЮЗ—7

Key: (1). Descending motions (mb/12 hour) on the surface (mb.). (2). Direction and wind velocity (m/s) on surface (mb.). (3). Mineral'nyye Vody. (4). Makhachkala.

FOOTNOTE [1]. Lower boundary of phenic flow lay/rested above surface of 850 mb.

[3]. There was no data about wind. ENDFOOTNOTE.

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In cases when on the windward side of mountains fell precipitation, the values of the descending motions for the surfaces of 850 mb., calculated according to the values of the dew point, varied in the limits of 40-130 mb. in 12 hours. Certainly, in the presence of condensation change in the dew point does not give any precise values of vertical motions of air. However, these numerals nevertheless indicate that the air, which was dropped/omitted from the lee side to the surface of 850 mb., was located on the windward side of mountains, it is lower than their apexes/vertexes, i.e., was observed the classical foehn of shifting/passing [1].

The speed of the depression of air on leeward slope of mountains depends on the series/number of the reasons: from the stability level of atmosphere, superposition on the foehn effect of the regulated vertical motions, etc. One of the basic reasons must be also the speed of the outflow of air in the lower layers of atmosphere from the mountains from the lee side of mountains. It is more, the fact, other conditions being equal, of greater must be the speed of

the depression of air. For the confirmation of this latter/last two graphs/counts Table 3 gives direction and wind velocity in Mineral'nyye Vody and Makhachkala on surfaces of 850 and 700 mb. They show that in cases when in entire layer (850-700 mb.) is observed the wind, close to the southwest, i.e., the outflow of air occurs in the direction perpendicular to the ridge/spine, the value of the descending motions, as a rule, is more than in cases when wind direction in this layer with the height noticeably is changed or strongly differs from the southwest.

Arises question, to what extent are precise the values of descending air motion, the calculated during the utilization dew point. For checking this were found those values of temperature and deficiency of the point of dew which must be observed on surfaces of 850, 700, 500 and 400 mb. in Mineral'nyye Vody and Makhachkala in the examined in Table 3 cases under the condition of the dry adiabatic heating of air with its depression. Furthermore, were calculated the differences

$$(t_H - t_h) - (t'_H - t'_h),$$

where t_H and t_h - actual, t'_H and t'_h - calculated values of the temperature in the final period of observations on the lower- and the overlying basic isobaric surfaces. Each of these differences characterized the difference between the actual and calculated lapse rate in the appropriate layer. The obtained results are given in

Table 4, where the cases examined are written in the same order, as in Table 3.

From the data of Table 4 it is evident that the calculated temperature, as a rule, is higher than actual. On the surface of 850 mb. differences in a number of cases they reach 5°, with the height they decrease. Large differences for Mineral'nyye Vody were obtained in essence within the night period of observations, that it is possible to explain by the effect of the nocturnal cooling. Furthermore, into cold half of year to a certain extent is manifested the transformation cooling of the air, which moves to the north.

The differences between the actual and calculated deficiencies of the dew point on the whole of less than differences in the actual and calculated temperatures and in the overwhelming majority of the cases are within the limits of accuracy of observation. Some inaccuracies in calculation it is possible to explain by utilization of data of radiosounding in Sukhumi and Tbilisi, while in actuality initial points in the trajectory of air particles could be located from them at certain distance.

The differences between the actual and calculated lapse rates are very small.

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The lapse rates, expressed in the degrees on 100 m of height, do not exceed, as a rule, several hundredths of degree and sometimes they only reach 0.1°. Thus, data of Table 4 make it possible to assert that the values given in Table 3 for descending air motion are close to the actual ones.

Let us examine synoptical conditions, with which are formed the foehns in the North Caucasus. Foehns appear either on the eastern and southeastern periphery of the cyclones, moving from the Black Sea or the Balkan peninsula to the northeast or on the southwestern periphery of vast anticyclones with center above Kazakhstan or Western Siberia.

With the foehns on the periphery of cyclones usually is observed heat advection, and in the rarer cases advection is absent. Foehns in the anticyclones frequently appear with cold advection. Cold air enters in the North Caucasus on the periphery of anticyclone from the southeast. In these cases the temperature on leeward slope of mountains with time in the majority of the cases is reduced, but a temperature decrease proves to be considerably less than the advective.

Table 4. Differences between the actual and calculated values of meteorological elements on different surfaces (mb.).

(1) Конечный срок	(2) Разности между фактическими и вычисленными значениями: (3) температуры				(4) дефицитов точки росы				$(t_H - t_h) - (t'_H - t'_h)$ (5) для слоев (мб)		
	850	700	500	400	850	700	500	400	850—700	700—500	500—400
(6) Минеральные воды											
(7) 15 час. 9/XI	—2	0	1	1	—2	0	0	—1	—1	0	1
11 час. 20/XII	—3	—4	—2	0	—2	—2	—3	0	0	—2	—1
3 часа 10/XII	—5	—2	—3	—3	—5	—4	—2	0	—2	—1	—1
3 часа 10/XII	—5	0	—2	—3	—3	0	—2	—1	—3	—2	1
3 часа 13/II	0	—4	0	0	—4	0	0	0	3	—3	0
15 час. 29/IX	—1	—2	—1	—1	—1	2	2	1	—1	1	0
15 час. 10/X	0	3	1	—1	3	3	0	—2	1	0	—3
3 часа 16/X	—5	1	—1	—2	—3	—3	0	—1	1	2	0
15 час. 21/XI	—1	0	1	0	0	0	1	0	—1	—1	0
3 часа 29/IX	—1	—4	3	—3	—1	1	0	2	—1	0	2
3 часа 30/IX	—2	—4	—3	0	0	1	0	1	1	0	0
3 часа 3/XII	—3	—2	—1	1	—2	—1	0	1	0	—1	—3
3 часа 9/XII	—4	—4	—4	—2	—2	—3	0	0	0	0	—2
(8) Махачкала											
(7) 3 часа 26/XI	1	0	0	0	—1	—2	0	0	—1	—1	1
15 час. 19/III	—4	—4	0	1	—2	—5	0	1	2	—5	—1
15 час. 30/IX	—2	—4	—2	—1	—1	—4	—1	0	1	—2	1
15 час. 19/IX	—2	—1	—2	0	0	3	0	1	—2	1	—1
15 час. 13/XII	—1	—2	—2	—3	—1	—3	—2	—1	—1	—2	0
3 часа 29/XI	0	2	4	2	—2	2	2	2	0	0	3
3 часа 2/XI	0	1	3	3	—1	0	0	0	—1	0	—1

Key: (1). Final period. (2). Differences between actual and calculated values. (3). temperature. (4). deficiencies of dew point. (5). for layers (mb.). (6). Mineral'nyye Vody. (7). hour. (8). Makhachkala.

FOOTNOTE [1]. Lower boundary of the foehn flow lay higher than surface of 850 mb. ENDFOOTNOTE.

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Cyclonic foehns occur more frequently than anticyclonic. From 78 cases of foehn 48 examined were observed in the cyclones and 30 in the anticyclones. According to work [4], the duration of foehns in the North Caucasus can oscillate from several hours to 10-15 days. The duration of foehn depends on the time of the retention/preservation/maintaining the character of pressure field, which conditioned foehn. Since the southern cyclones, as a rule, are movable, and in the anticyclones above Kazakhstan frequently becomes apparent tendency toward stationarity, anticyclonic foehns on the whole are more prolonged than the foehns, which appear on the periphery of cyclones. Cyclonic foehns frequently exist less than 12 hours. They are observed usually in by heat the sector of cyclone and cease after the passage of cold front.

Foehn air, after descending from the mountains, ebbs from them together with the flow, retaining its properties. Frequently on the temperature and the humidity it is possible to trace, how the

entrained by air flow foehn air at levels 850 and 700 mb. by relatively narrow band will move away increasingly further and it is further from the Caucasian mountains to hundreds of kilometers.

The distance from the mountains, at which are retained the foehn properties of air, is determined by pressure field. If the air descending from the mountains is moved further in the cyclonic field, then, testing/undergoing the here ascending motions, phenic air rapidly loses its properties. In cases when the phenic air above the European territory of the USSR is moved in the region of anticyclone, the descending motions contribute to retention/preservation/maintaining by air of foehn properties during the long time.

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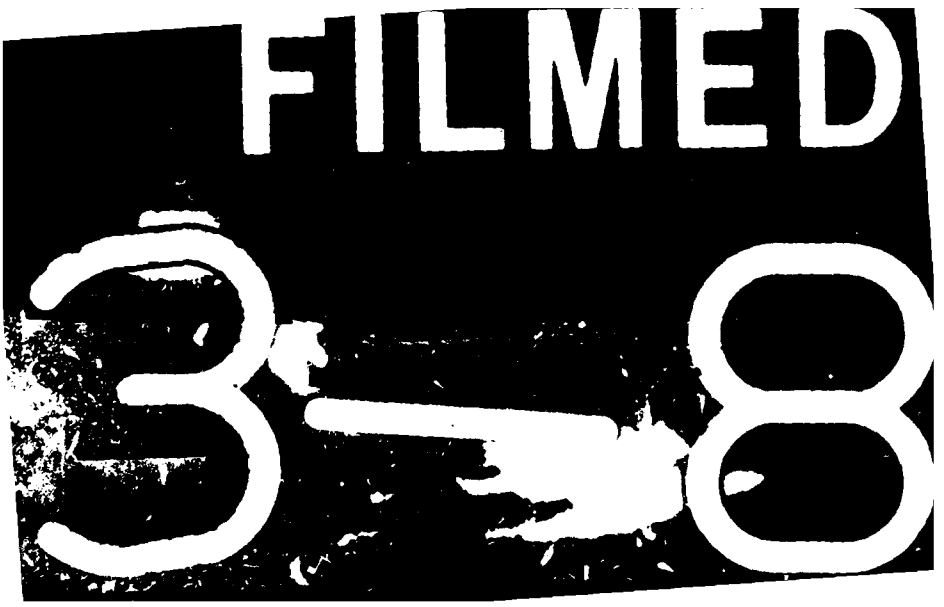
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